

# Power Technology and Alternative Energy Branch

US Army RDECOM CERDEC C2D Army Power Division  
Aberdeen Proving Ground, MD



PTAE - TR - 09 - 01

## CERDEC Co-generation and Absorption System Targets and Enabling Technologies

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## CERDEC Co-generation and Absorption System Targets and Enabling Technologies

IAPG Mechanical Working Group  
Meeting, Philadelphia, PA

06 May 2009 08:30 AM



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

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Power Technology and Alternative Energy (PTAE) Branch  
Aberdeen Proving Ground, Maryland

- Introduction
- Combined Cooling, Heating, and Power (CCHP) Technologies
- CCHP Applications
- CCHP Opportunities
- Closing



# Army Power Division

## US Army RDECOM CERDEC C2D



### Army Power Division

Engineering  
Support  
Branch

Power  
Sources  
Branch

Experimentation  
and Simulation  
Branch

Power Technology  
and Alternative  
Energy Branch

Renewable Energy Team

Electromechanical Team

Special  
Projects  
Office

APG, MD 2011



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# Mission Summary

## *CERDEC Renewable Energy Team*



### **Enabling Technologies**

- Photovoltaic and Solar Concentrators
- Wind Turbines
- Fuel Processing, Waste-to-Energy, and Synthesis Gas to Liquids
- Thermoelectric
- Heat-actuated Cooling & Co-generation

### **Applications**

- Tactical Mobile Power
- Vehicle-mounted Auxiliary Power and Environmental Control
- Portable Renewable and Fueled Power Sources
- Energy Security for Installation Operations
- Waste abatement

### **Objectives**

- Fuel Efficiency
- Force Protection
- Improved Mobility
- Reduced Signatures
- Reduced Logistics

# CCHP Technologies



# US Army CERDEC CCHP *Technologies & Objectives*



- Enabling Technologies:

- Novel heat exchanger geometries/materials, compressor designs, fluid handling/mixing, refrigeration cycles, and work recovery devices
- Vapor compression – low-GWP fluorocarbons and natural refrigerants
- Absorption – ammonia, lithium-bromide, and other novel cycles
- Adsorption – zeolite/silica-gel/graphite/desiccant sorbents and heat pipes
- Organic Rankine Cycle (ORC) and other waste energy utilization processes

- Objectives:

- Combined power and environmental control units (reduced size, weight, and parasitic loads compared to stand-alone configuration)
- Improved power generation and/or environmental control efficiencies
- Safer, more environmentally-friendly refrigerants (non-flammable, low global warming, and zero ozone depletion)
- Reduced logistics, maintenance requirements

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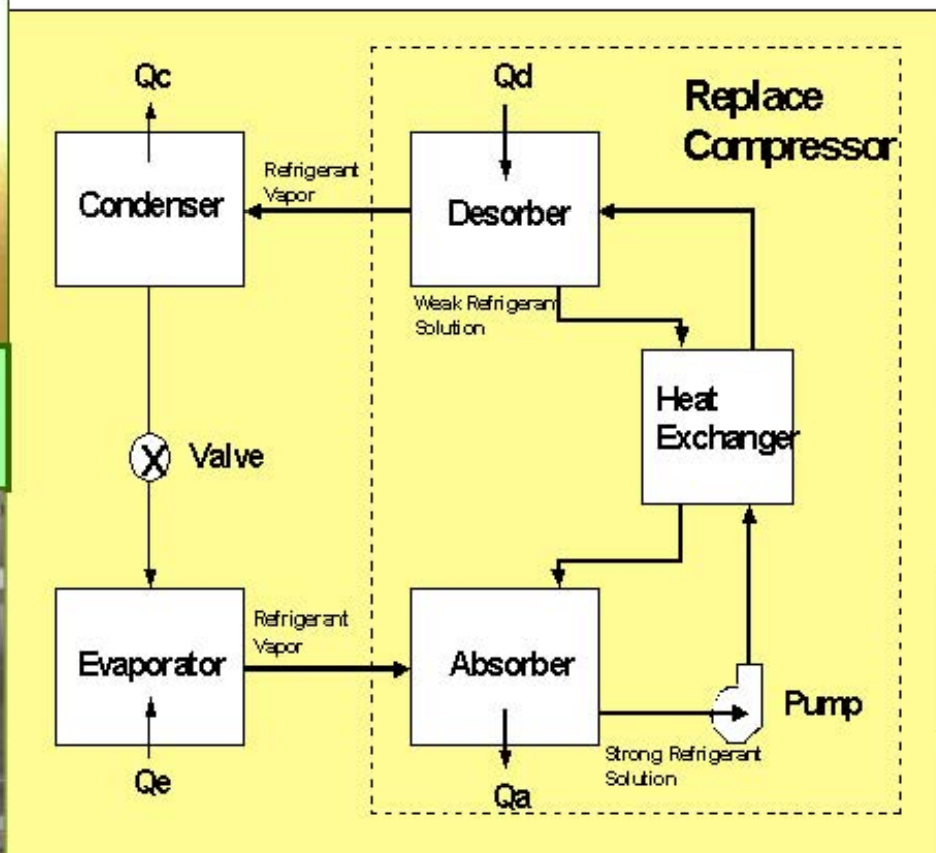




# US Army CERDEC CCHP *Ammonia-Water Absorption*



**Fractal Desorber  
(100  $\mu\text{m}$  channels)**

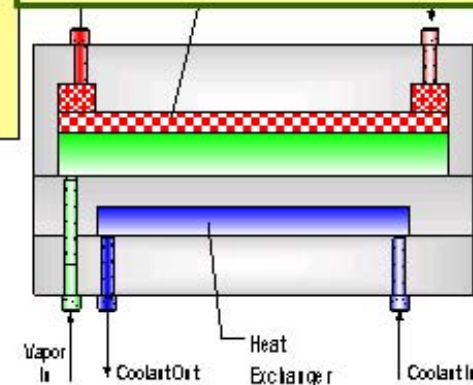


Work to-date performed in cooperation with Pacific Northwest National Lab (PNNL), Oregon State University, University of Oregon, and Portland State University

TRL 3 Breadboard Demonstrated FY08 (COP ~0.4)  
TRL 4 Integrated Demonstrator in FY10



**Microwick Absorber  
(310  $\mu\text{m}$  channels)**



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# US Army CERDEC CCHP *Perspectives on Technologies*



- Absorption-Specific Technology Hurdles:
  - Smaller, lighter, more efficient vacuum pumps for lithium-bromide (Li-Br)
  - Novel ways to prevent / mitigate crystallization for Li-Br
  - Increase coefficient of performance (COP) of ammonia-water absorption to be comparable with lithium bromide<sup>1</sup> and all absorption COP to be comparable with VC
  - Ammonia release monitoring, prevention, and mitigation
  - Operation on low-quality waste heat from power source
- Generalized CCHP Technology Hurdles:
  - Operation in extreme cold environments below water freezing point
  - Longevity and safety characteristics of various sorbents and desiccants
  - Some CCHP technologies that show potential for very low system dry weight have inferior fuel consumption compared with traditional systems already in-use
  - Lowering the cost/availability of microchannel heat exchangers to tube and fin prices through breakthrough manufacturing process development
  - Part-load performance of power source and/or waste energy recovery devices
  - Some of best work recovery devices also tend to be the loudest (turbines, etc)



## US Army CERDEC CCHP *Perspectives on Refrigerants*



- The low-GWP refrigerant replacements:
  - Replacements for R-134a in vehicular heating ventilation and air conditioning (HVAC) systems are still being debated (CO<sub>2</sub> vs. HFO-1234yf)
  - Replacements for R-22 are tentatively R-407 and R-410a, which have been agreed upon as the near-term standards for stationary / mobile HVAC units by PM MEP
- Flammable and/or toxic fluids for either application will be a tough sell to the Army requirements and safety communities (hydrocarbons, HFO-1234yf, ammonia, metal hydrides, etc.)
- Thermal degradation, performance, and safety characteristics of each refrigerant should be well-understood prior to system development/integration



# CCHP Applications





# Project Manager Mobile Electric Power (PM MEP) Managed Items<sup>2</sup>



## Small Sets

- 2kW Military Tactical Generator, Manportable/Skid Mounted, Diesel/JP8 Fueled, AC(60Hz) and DC(28VDC)
- 3kW Tactical Quiet Generator, Skid Mounted, Diesel Fueled (60 Hz and 400Hz)



## Medium Sets

- 5kW, 10kW, 15kW, 30kW, and 60kW, Skid Mounted, Diesel Fueled Tactical Quiet Generator, 60Hz and 400Hz
- AMMPS – Advanced Medium Mobile Power Sources



## Large Sets

- 100kW and 200kW Tactical Quiet Generator (TQG), Skid Mounted, Diesel Fueled, 60Hz
- 840kW Deployable Power Generation and Distribution System (DPGDS), Diesel Fueled



## Power Distribution Illumination System Electric (PDISE)

Man-portable, Reliable, Modular, Quick Assembly Standardized Electrical Management and Distribution System Components

40 AMP/PHASE DISTRIBUTION SYSTEM  
60 AMP DISTRIBUTION SYSTEM  
100 AMP/PHASE FEEDER SYSTEM  
200 AMP/PHASE FEEDER SYSTEM  
UTILITY RECEPTACLE AND LIGHTING KIT



## Power Unit/Power Plant (PU/PP)

- Trailer Mounted Tactical Quiet Generators in the 3kW, 5kW, 10kW, 15kW, 30kW, 60kW, 100kW, and 200kW Power Ratings.
- 20 Different Models That Use 4 Different But Standardized TACOM Trailer Models



## HI-POWER

### Hybrid Electric Intelligent Power Management

Develop a Tactical Hybrid-Electric Power System for use at Forward Operating Bases to minimize logistics fuel consumption related to power generation.



## Improved Environmental Control Units (IECU)

New Generation of ECUs Utilizing Zero Ozone Depleting Refrigerants. Ruggedized Form, Fit, and Function Replacement Systems with Embedded Diagnostics.

9K, 18K, 36K, and 60K BTUH sizes.





# HCFC R-22 Phase-Out



## Clean Air Act - Phase-Out of Production and Consumption of R-22

	2000	2004	2010	2015	2020	2030
HCFC (R-22) Prod'n. Phaseout	UNLIMITED PRODUCTION		Pre-2010 EQUIPMENT SPT			
R-22 in Equipment (U.S.)	NEW EQUIPMENT		SERVICE EXISTING EQUIPMENT			

### Operational Requirements Document approved October 2004

- Blk I: Zero ozone depleting refrigerants
- Blk II: Blk I plus Zero-net Global Warming
- Blk III: Blk II plus self-powered w/Exportable Power

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# US Army Environmental Control Unit (ECU) Roadmap



TODAY	Block I	Block II	Block III
TECHNOLOGY			
VAPOR CYCLE			Cogeneration Cooling/Heating
HCFC (R-22)	HFC Blends (R-407/410)	Natural Refrigerants (CO2)	
ENVIRONMENTAL			
Non-zero ODP Non-zero GWP	Zero ODP Non-zero GWP	Zero ODP Zero-net GWP	Zero ODP Zero-net GWP
LOGISTICS			
Recovery/Recycle Service Equipment	Recovery/Recycle Service Equipment	No Special Service Equipment	No Special Service Equipment
PERFORMANCE			
Baseline	Weight - 15% Less Size - Same Energy - 10% Less	Weight - 25% Less Size - 25% Less Energy - 25% Less	

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**APU**

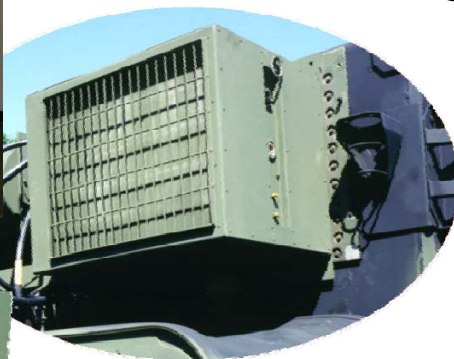
**ECU**

## • Fielded System<sup>3</sup>:

- 290-kg total dry weight (ECU+APU)
- 1-gal/hr (3.8-L/hr) fuel consumption
- 75-dB(A) inside shelter
- 208-kg, 10-kWe APU
  - 3600-rpm turbocharged engine
- 82-kg, 5.3-kWt (1.5-ton) ECU
  - Vapor compression
  - Split-pack with R-134a

## • CERDEC FY11 CCHP Targets:

- TRL-5: Integrated demonstrator
- 205-kg total dry weight (ECU+APU)
- 0.7-gal/hr (2.6-L/hr) fuel consumption
- 55-dB(A) inside shelter
- 3-kWe net power, 5.3-kWt cooling







- Fielded System<sup>3</sup>:
  - 1120-kg total dry weight (ECU + Gen)
  - 1.5-gal/hr (5.7-L/hr) fuel consumption
  - 920-kg, 15-kWe Tactical Quiet Gen (TQG)
  - 200-kg, 10.5-kWt (3-ton) ECU
    - Vapor compression (VC)
    - Unitary with R-22
- Next-Generation (AMMPS and IECU):
  - 994-kg total dry weight (ECU + Gen)
  - 1.275-gal/hr (4.8-L/hr) fuel consumption
  - 814-kg, 15-kWe AMMPS
  - 180-kg, 10.5-kWt (3-ton) IECU (VC, R-410a)
- CERDEC FY11 CCHP Targets:
  - TRL-5: Integrated demonstrator
  - 840-kg total dry weight (ECU + Gen)
  - 1.05-gal/hr (4-L/hr) fuel consumption
  - 5-kWe net power out , 10.5-kWt net cooling

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# CCHP Applications

## Mission Weight Analysis



### Mission Weight: Various Technologies

#### SICPS Application

<u>Mission time</u>	<u>Baseline</u>	<u>Target</u>
<i>GAL/HR:</i>	<i>1</i>	<i>0.7</i>
<b>hour</b>	<b>kg</b>	<b>kg</b>
0	290	205
40	410.8	289.56
80	531.6	374.12
120	652.4	458.68
160	773.2	543.24
200	894	627.8
240	1014.8	712.36
280	1135.6	796.92
320	1256.4	881.48
360	1377.2	966.04
400	1498	1050.6
440	1618.8	1135.16

#### Tent Application

<u>Mission time</u>	<u>TQG</u>	<u>AMMPS</u>	<u>Target</u>
<i>GAL/HR:</i>	<i>1.5</i>	<i>1.275</i>	<i>1.05</i>
<b>hour</b>	<b>kg</b>	<b>kg</b>	<b>kg</b>
0	1120	994	840
40	1301.2	1148.02	966.84
80	1482.4	1302.04	1093.68
120	1663.6	1456.06	1220.52
160	1844.8	1610.08	1347.36
200	2026	1764.1	1474.2
240	2207.2	1918.12	1601.04
280	2388.4	2072.14	1727.88
320	2569.6	2226.16	1854.72
360	2750.8	2380.18	1981.56
400	2932	2534.2	2108.4
440	3113.2	2688.22	2235.24

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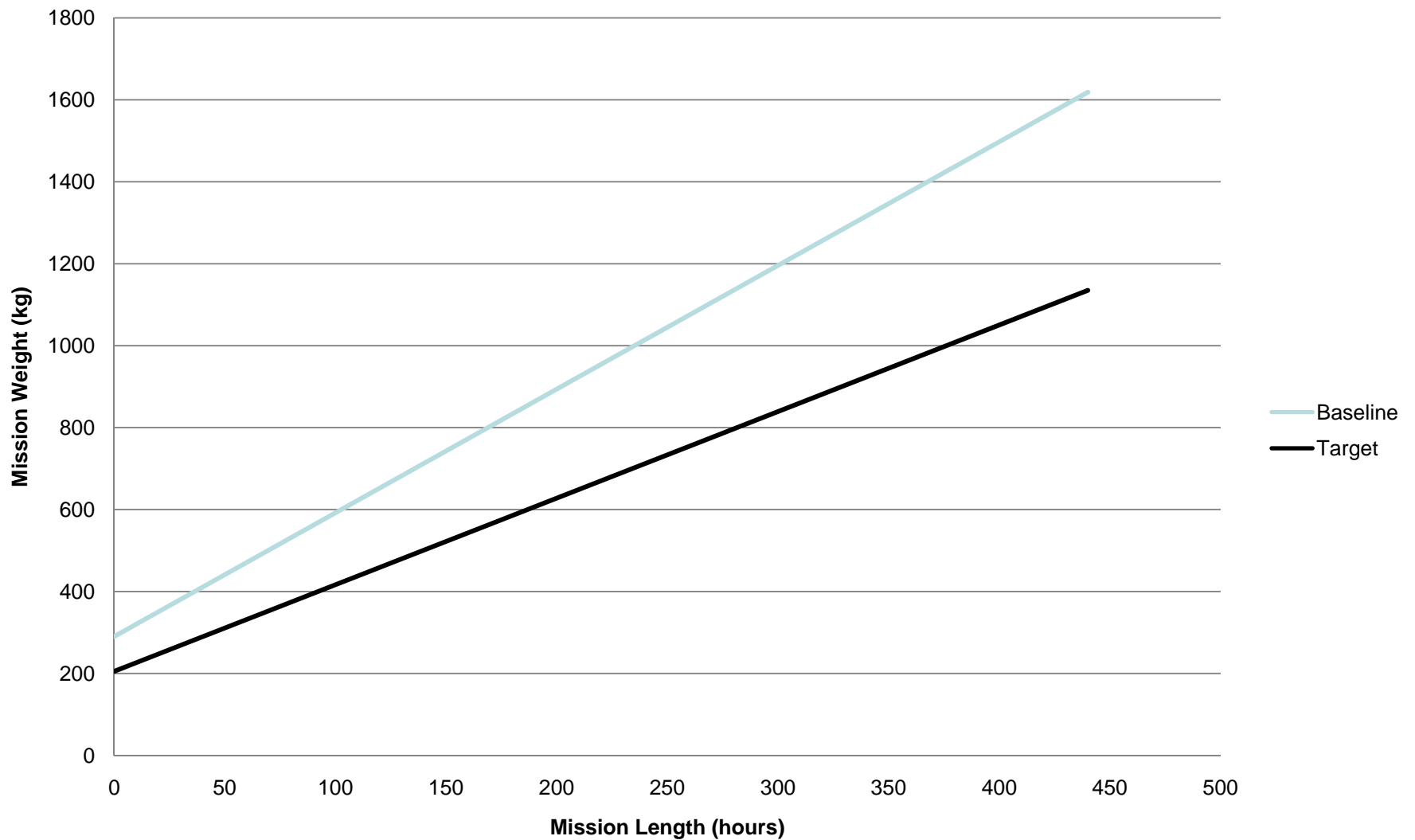


# SICPS

## *Mission Length vs. Mission Weight*



### CCHP Systems for a 3-kWe / 5.3-kWt SICPS Application



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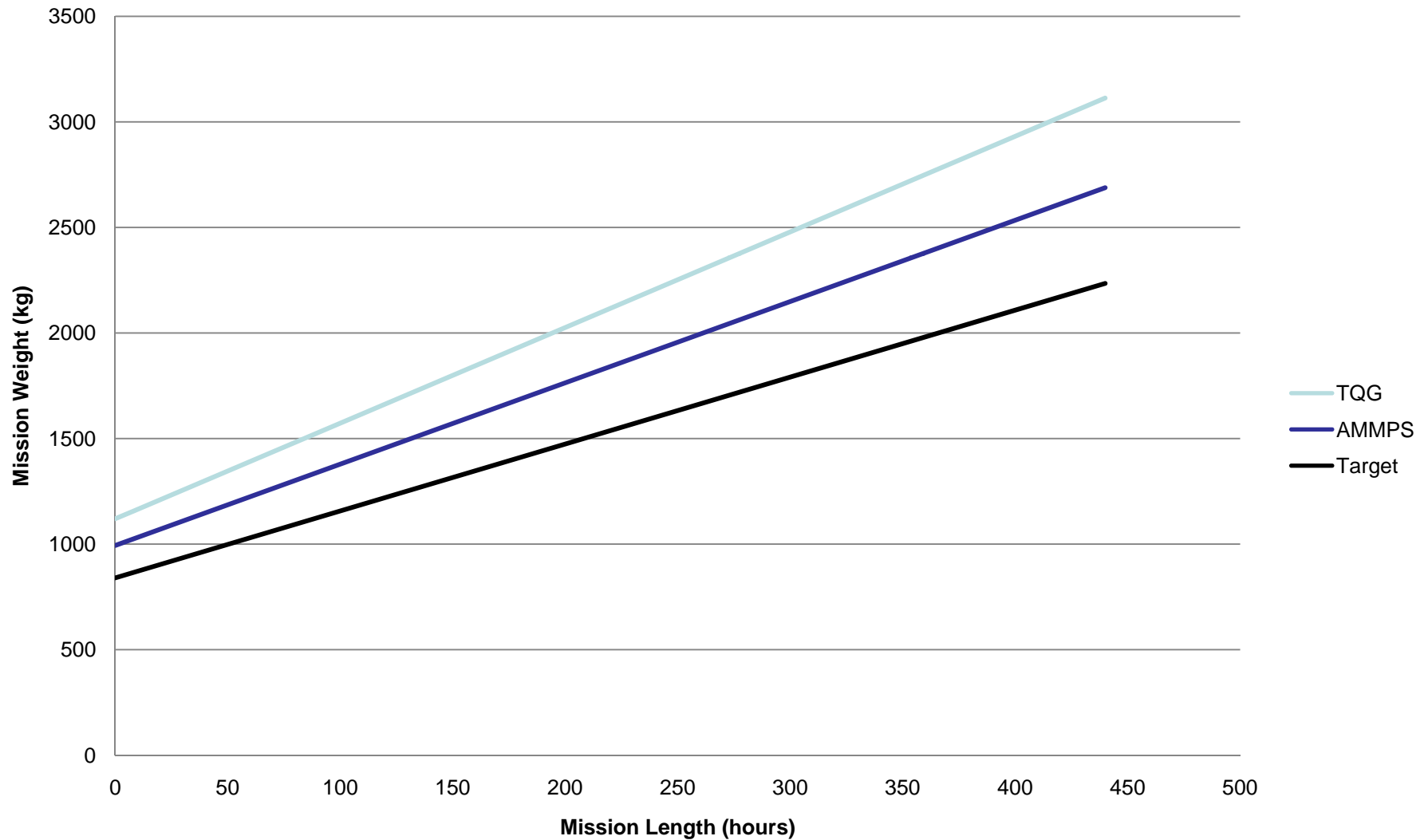


# SICPS

## *Mission Length vs. Mission Weight*



### CCHP Systems for a 5-kWe / 10.5-kWt Tent Application



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- **RECOVERY / STIMULUS** for Smaller Lighter Co-generation and Absorption Environmental Control Technologies
  - BAA #W909MY-09-R-0011
  - Released: 13 Apr 2009, Closes: 15 May 2009
  - Proposals that show the greatest potential to fully-address one or both topics while simultaneously **creating or retaining the greatest number of jobs** are preferred
- **Small Business Innovative Research (SBIR)**  
**Topic #A09-090** - Heat Actuated Cooling
  - Now in pre-solicitation
  - Proposals accepted from 18 May 2009 until 17 June 2009



# Closing



- Microchannel heat exchangers, ejector heat pumps, and other near-term CCHP component enhancements hold significant promise, but require manufacturing and process technology development prior to becoming cost-competitive with tradition VC
- Major component-level technical breakthroughs are needed to bring absorption technologies to the field and make them competitive on a weight and size basis with VC and other CCHP
- Refrigerant characteristics need to be determined up-front: toxic, flammable, and/or expensive fluids will be a tough sell to the operational community
- Low dry weight for a CCHP system is NOT viewed as favorable by the user community if fuel consumption exceeds that of the baseline
- Know your system's waste heat characteristics over entire operational profile PRIOR to designing your waste energy recovery device (especially at part-loads)

1. Horuz, I. "A comparison between ammonia-water and water-lithium bromide solutions in vapor refrigeration systems." International Communications in Heat and Mass Transfer, Vol. 25, Issue 5, July 1998, Pg. 711.
2. Richard, Paul. "Mobile Electric Power for Today and Tomorrow." Joint Service Power Expo, 25 April 2007. PM MEP Website: [http://www.pm-mep.army.mil/pdf/files/Joint\\_Service\\_Power\\_Expo\\_25\\_Apr07.pdf](http://www.pm-mep.army.mil/pdf/files/Joint_Service_Power_Expo_25_Apr07.pdf)
3. Department of Defense (DoD) Project Manager for Mobile Electric Power (PM MEP) Website: <http://www.pm-mep.army.mil/technicaldata/index.htm>